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Two mathematical models of paired-associate learning were used to develop optimal strategies for presenting spelling words to 42 elementary school children. The study was conducted within a computer-based drill-and-practice project. For the study two computer programs were developed. One program presented and corrected the lists of words. The other program planned lessons for each child as a function of the mathematical model the words represented, the words the child was studying, and the child's performance on the words. An analysis of the correct responses made by each child through the study demonstrated that the strategy derived from the One Element Model produced significantly better terminal performance than the strategy developed from the Single Operator Linear model. (Author)

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FINAL REPORT

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COMPUTER-BASED INSTRUCTION IN SPELLING: AN INVESTIGATION OF OPTIMAL STRATEGIES FOR PRESENTING INSTRUCTIONAL MATERIAL

April 1969

U.S.DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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Computer-based instruction in spelling: An investigation of optimal strategies for presenting instructional material.

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April 1969

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INTRODUCTORY SECTION.

SUMMARY

Optimal strategies for presenting items in computerized spelling drills were developed from two mathematical models of paired-associate learning. The effectiveness of the strategies was then tested on 42 elementary school children from a "disadvantaged" area.

The strategies tested included one based on the One Element Model and one based on the Single Operator Linear model. Two different presentation routines were developed as a function of the assumptions underlying each of these models.

In addition to developing presentation routines, two programs were devised to implement the project on the computer based instructional system of the Institute for Mathematical Studies in the Social Sciences. The first program provided a fairly flexible lesson presentation scheme. The program also provided a certain amount of individualized encouragement to each student through the use of variable evaluative comments.

The second program developed for this project was used to plan lessons for each student as a function of the words he was studying, the presentation routine each word was under, and the student's daily performance.

An analysis of the correct responses made by the students during the course of the study showed the presentation routine based on the Single Operator Linear model produced more correct responses during training but yielded significantly poorer terminal performance than the presentation routine derived from the One Element Model.

Implications from the study include the need to investigate the affective consequences of the finding that the best learning results from a routine which, in a sense, maximizes the student's failure during training.

INTRODUCTION

The purpose of this study was to compare two strategies for presenting words in computer-based spelling drill. The presentation strategies chosen for comparison were developed from two mathematically-based models of paired-associate learning.

The two strategies were based on mathematical models of learning to improve the precision with which theoretical assumptions about the learning process could be applied and tested in an instructional setting. To develop an instructional strategy one must make assumptions about how learning takes place. The more explicitly these assumptions are introduced, the more precisely the results of instruction can be used to judge the validity of the origional assumptions. Such a view has been advanced by Groen and Atkinson (1966) in their paper "Models for Optimizing the Learning Process."

If learning occurs in accordance with the assumptions of some specific model then an instructional strategy based on such a model will produce efficient and effective learning. A strategy based on the model could be called "optimal", in terms of the Groen and Atkinson (1966) discussion. To refine their argument, these authors further distinguish bewteen strategies which are and which are not response sensitive. As examples, they offer the One Element Model (OEM) (Bower, 1961; Estes, 1960) which provides a response sensitive strategy as optimal, and the Single Operator Linear model(SOL) (Bush & Sternberg,1959), which provides a response insensitive strategy as optimal. In this study item selection strategies for the spelling drill were based on optimal strategies derived from a response sensitive and a response insensitive model of paired-associate learning.

The response insensitive optimal strategy as based on an incremental view of learning. Clark Hull (1943), for example, advanced this position through such remark as, "Habit strength is an increasing function of the number of reinforcements (p.113)." Mathematical models of learning based on the assumption that the underlying process is a linear function of the number of presentations of a corrected item such as the Single Operator Linear model are built on assumptions of this type. The kind of model assumes that each reinforced (in terms of "knowledge of results", for example) association of a stimulus with its response brings about a decrement in the probability of an error. Notice that these models are based on the response insensitive assumption that it is the reinforced presentation of an item that affects the probability

of a correct response without regard for whether an actual response was right or wrong. Given a list of unlearned spelling words and this view of learning, the most efficient way to procede would be to present and reinforce every item equally often. One of the item selection strategies in the present study was to offer items in the manner mentioned.

The second strategy chosen for the study was based on the response sensitive assumptions of the One Element Model mentioned above. This model is based on the assumption that stimulus and response associations are made on an "all-or-none" basis. The view has been advanced by such learning theorists as Guthrie (1952) and, with greater precision, Estes (1964).

Briefly, the One Element Model (OEM) assumes that the subject is in either the conditioned(learned) or unconditioned (unlearned) state with respect to a stimulus-response pair. A correct response is given with probability 1.0 when the subject is in the conditioned state. A correct response may be given (with some probability "g") when the subject is in the unconditioned state and guesses correctly. An incorrect response occurs when a subject in the unconditioned state guesses incorrectly (with probability "1 - g"). The model also states that, with a certain constant probability, the learner will move from the unconditioned to the conditioned state. Changes in state take place only when an item is presented and reinforced.

Notice that this model produces a view of the learner's performance that calls attention to the responses made. An incorrect response means that the subject has not "learned" the item. A correct response means, with a computable probability, that the subject has guessed correctly or has learned the item. Using this "response sensitive" feature of the model and relying on a theorem developed by Karush & Dear (1966), Dear, Silberman, Estavan, and Atkinson (1967), developed a set of rules for an optimal presentation strategy. The presentation rules, which were used in their paired-associate learning experiment, were:

1. Administer any item in a presentation set to the subject on the first trial.
2. At the next trial, after a subject's incorrect response to an item, present that item to him again.
3. At the next trial, after a subject's correct response to the current presentation, present to him the item to which he has made the smallest number of incorrect responses following his last correct response to the item.

4. If several items are eligible under rule 3, select from these the item that has had the smallest number of presentations. If several items are still eligible, select with equal probability from the set. (Dear, et al.,1967, p 5)

Dear,et al.(1967) compared the strategy defined by these rules with one based on the incremental assumption discussed earlier. Their work failed to prove the efficacy of either strategy. The results could be interpreted as indicating a more complicated learning model is needed on which to base the optimization routine. This is the position taken by Groen and Atkinson(1966). However, the lack of definitive results in Dear, et al.(1967) could have been due to some confounding factors. The fact that the test session immediately followed the last practice session in a cycle gave an advantage to the incremental strategy since all the S-R pairs in this list had just been seen and a short term memory factor could have influenced performance. Further, a ceiling effect may have operated because of the large number of trials on very simple material.

The study reported here followed closely the methods and strategies of the Dear,et al.(1967) study. Several changes were made in order to eliminate the confounding factors just mentioned. First only one trial per day on the selected subset of words was allowed. The insertion of about 24 hours between trials sought to eliminate effects due to short term memory factors. Secondly the material used consisted of spelling words of proven difficulty for each subject in the sense that each subject's list was made of words he had spelled incorrectly in a pre-test. Finally, to increase the generality of the results as well as to move the test of these models into an applied setting, elementary school children were used rather than the college students used by Dear, et al.(1967).

METHODS

SUBJECTS.

For this study, the children from two intact classrooms were used. The classes were located in an elementary school which served a culturally disadvantaged area where the majority of families are non-Caucasian. Economically the area is best characterized as lower middle class since most of the dwellings in the surrounding area are single family units. Previous studies, such as Knutson (1967), have found the students generally score below grade level on achievement measures and below average on measures of general ability. While the children in this study can be viewed as atypical in many ways, it is not likely that the way in which they learn is qualitatively different from other children. Indeed, one of the oft cited potential advantages of computer based instruction is that it would allow individual students to achieve as a function of their "real" potential rather than as a function of their class or cultural origins. Further, since each child was his own control, it is improbable that the findings are unique to the subculture of which these children are a sample.

Although during the 1967-1968 school year more than 120 children interacted with the Spelling Project material on a regular basis, only 42 children participated throughout this investigation. The 42 subjects used in the study included 17 boys and 25 girls from two classes. Twenty children came from a combined forth and fifth grade class. The rest of the children were members of a sixth grade class. Since, as will be elaborated, the spelling words studied by each child were selected for him in an extensive pre-testing period, each child studied words appropriate to his ability and his need (only the words a child had misspelled were included on his list).

EQUIPMENT.

The lesson material was presented on teletypewriters and through headsets over telephone lines linked to the Computer Based Laboratory of the Institute for

on the Stanford University campus. At this laboratory are located the several computers which have been built into a unique system for presenting instructional material.

The main computer in this system was a Digital Equipment Corporation Programed Data Processor - 1D. The PDP-1D is a single address, 18 bit word length, binary machine. The machine has 32,768 words of core memory of which 16,384 are used by the time-sharing operating system. The two main spelling programs (described below) operated in 4096 words of core memory as one user. The time sharing operating system allows up to 26 such users to run on the computer at the same time. Basic to this time sharing system is a very high speed "drum" used to hold programs not actually running in the computer. By trading programs in and out of the core memory from this drum, the operating system shares the available machine time among several programs greatly increasing the power and flexibilty of the machine.

The PDP-1 communicated with the student stations at the school through two smaller computers. A DEC PDP-8 was used to handle communication with teletypewriters. A Westinghouse Prodac-50 computer controlling twelve random access tape drives provided the means for sending recorded audio messages to each student station. These tape drives were experimentally designed to record and play six inch wide tape-loops consisting of 128 parallel tracks further subdivided into eight one-second segments. The audio message associated with each word used a four-second block of tape allowing 256 words to be recorded on each tape-loop.

PROCEDURES.

Computer Programs.

Two separate programs were written for the project. The main effort was with the Lesson Implimentation Program. The main interest of the study was, however, with the Lesson Optimization Program.

Lesson Implimentation Program (LIP)

LIP's main task was to present each spelling word orally, monitor and check the child's attempt to spell the word and provide feedback to the child on the correctness of his attempt. In so far as possible, consistent with an orderly, paced lesson, the child was allowed a certain amount of flexibility in what he did and, through the proctor on-site with the children, was allowed access to several options which could restructure his lesson as the circumstances warrented. Before discussing the very useful capability to modify the lesson flow from the teletypewriter, the normal flow of a lesson will be described.

As each child took his place at one of the four student stations he would see a varied "picture" and greeting with a request to type in his number. For example the last two weeks in April the students were greeted by:

22 APR 68

WHAT DO YOU THINK BRINGS MAY FLOWERS

PLEASE TYPE YOUR NUMBER... -

The student would type his two-digit student number. The program would acknowledge receipt of the number (with an "...OK") and fetch his history information which contained the lesson plan computed by LOP (described below). When the child's history and associated pointers were loaded into the proper places in the program, LIP would welcome the child to the lesson with a remark chosen from a pool of five periodically changed comments. For example, it would greet La Tanya Lee with:

HOPE YOU ARE EAGER FOR WORK, LA TANYA

or with:

A CHEERFUL HELLO, LA TANYA

By opening with a variable text string and including the child's first name a certain amount of the impersonal nature of the drill setting was removed. At the end of the opening comment the first audio message was played to test whether or not the reception was adequate. The voice said, "If you hear my voice, type an 'a'." At the same time, the teletypewriter printed:

IF YOU HEARD MY VOICE TYPE AN -A-

If the child was receiving the audio message properly he would type the "A", otherwise he would call the proctor for help.

If the audio output test indicated the device was working well, the 16-word lesson would start. For each word a 4-second recorded message would be played such as, "Argue. The brothers would fight and argue all the time." While this audio message was being transmitted to the child, the number of the word was typed at his station. Since each list was individually randomized a relative designation was typed. For a designator, alphabetic letters were used. If, as will be elaborated below, a child needed to return to a word then the alphabetic designation could be used. In addition to the relative number, the absolute location of the word in the master word list was also typed out. The absolute number allowed the proctor to know which word was being attempted in case a question occurred. It also meant that the on-site proctor could perform as an "audio-device" in the infrequent case that the mechanical audio system failed.

For example, if ARGUE was the first word in a lesson the printed message would be "A 46 2 -"; if ARGUE was the fifth word in the lesson then "E 46 2 -" would be typed.

After the word number was typed and the oral message was played the child started typing in his answer. Latencies were measured from the time the audio message started to the time the child typed his first character. As he typed in each word the student was allowed the "erase" or correct errors in his work. If the error was in the last character he typed, the student would type a "." . The last character would be erased from his answer and the shortened word printed out. The printing of the corrected word was done so that the child's chances of becomming confused would be reduced. In the following example the student wished to erase the third character:

```
A  46  2   -ARCU.
           -ARC.
           -ARGUE
```

He was then free to type out the corrected word. To prevent playing with this option, a student could only use it three times on any one word. To help correct words in which major mistakes had occured a "," could be entered which would erase the entire word the student had thus far typed. On the Model 33 Teletype keyboard the "," is entered by holding down the shift key and stricking the "." key. Thus both degrees of correction could be accomplished with the same key.

When a student felt satisfied with his effort, he would type a space and LIP would evaluate his answer. When the evaluation was complete, LIP would record the results and the "time to first character" latency on the student's history record and type on the monitor teletypewriter the student number, word number and an indication of the performance. Finally, LIP would tell the child how he had done by using one of twelve possible comments from three different groups ("right", "wrong" and "time-up"). Then, in all cases, the correct spelling would be printed below the student's work and he would have ten seconds to study the correct spelling. For example, an item correctly typed on the first try would look like [Quotes mark the student's typed effort]:

```
A  46  2   -"ARGUE"    ... GOOD WORK, GOT IT RIGHT
           -ARGUE
```

An incorrect item might look like:

```
A  46  2   -"ARQUE"    ... NOPE...FIND THE MISTAKE

           -ARGUE
```

LIP would repeat the routine 16 times unless otherwise instructed, then would end the lesson for the day by typing a random "goodbye" message and the student's first name. The program would then type out a Daily Report Slip for each child to keep as a personal record of his effort. The actual lesson sheets were retained by the proctor until the end of the experimental period to prevent self study from confounding the results. The typed output after the last word in the lesson had the following appearance:

COME BACK SOON, LA TANYA

---

22 APR 68

DAILY REPORT SLIP FOR

LA TANYA LEE

TODAY YOU ATTEMPTED 16 WORDS

AND YOUR SPELLED 14 CORRECTLY

...GOOD PROGRESS...

The dotted lines were used to separate the retained from the take home sections. The final comment on the report slip was, again, chosen at random from a pool of similarly encouraging remarks.

In addition to this normal flow of the lesson, certain opportunities to vary the flow were available to the student. Some of these were available to the student directly, some were available to the student through the proctor.

Options Available to the Student.

1. Erasure. As was mentioned above this feature allowed a child to correct typing mistakes or to catch spelling errors before they were evaluated. The child could erase the entire word he had typed or he could erase just the last character. In the latter case, the revised word was printed for the child so that he would not be confused by having a text string with extra letters and dots marked correct.

2. Repeat Recorded Message. To eliminate the possibility that a child might miss a word because of momentary inattention while the recorded message played, the division sign (question mark on a standard Teletype Model 33 keyboard) could be struck and the recorded message would be played again. There was no limit on the number of times a child could ask to have the word spoken again.

3. Access Relative Word. As a final feature directed toward making sure a child was credited only with spelling errors and not typing or inattention errors, a capacity to have the entire word repeated was included. By striking a special key the student could request a certain relative word be given.

Options Available through the Proctor.

Certain options available at the student stations were concerned with major modifications in the flow of the program. The use of these options was generally reserved for the on-site proctor.

1. Start Student Station. The relevant information held by the program as well as printed on the teletypewriter was initialized through exercising this option.

2. Sign-off Student Station. As the converse of the first option, this option forced all the relevant program held and teletypewriter printed information to the end of a lesson.

3. Switch to Alternate Group. In addition to the two classrooms working on the main study, a third and part of a fouth classroom were regularly engaged in spelling drills not associated with the optimization study. When drills were given children from these classes, the proctor would use the option to modify the program to accept their student numbers and present their lesson material.

4. Audio on/off. Whenever the recorded material became, for one reason or another, difficult to hear, the proctor could use this option to turn it off while she read the words. As soon as the touble was corrected, the option could be used to turn the message playing back on.

5. Restore Audio. At the first occurence of trouble with the recorded messages, the proctor could call on this option. All the known methods for quickly fixing difficulties in playing the audio messages would be automatically tried by the program. If none worked then the proctor would use option 5 above.

6. Type to Monitor. A monitor teletypewriter at the Computer Based Laboratory collected certain useful information while the program was operating. By exercising this option the proctor could leave messages for personnel at the Lab or even converse with them directly (two way communication was also possible through this option).

7. End Daily Run. At the end of each school day the proctor would call for this option. It was used to bring in the separate program (described on p. 16) that planned the next day's lesson for each student.

The options just described provided the user at a student station with both control over and flexibility within his lesson. This combination added necessary features to the drill and practice routines for teaching spelling. Most important, with the options available to the student directly, it was no longer the case that a garbled audio message or a simple typing mistake meant the child would be marked wrong unjustly as had often been the case in previous spelling drill programs.

Lesson Optimization Program (LOP)

At the end of each day the on-site proctor would instruct LIP that the lessons for the day had ended. LIP would then read-in, over itself, the Lesson Optimization Program [LOP]. LOP was written to plan each lesson in the experiment. Given the child's history record of 48 words, LOP went day-by-day through the experiment forming each child's lesson for the following day on the basis of the particular word, the model it was being presented under, and the child's performance on the current day. LOP also collected and saved, in both binary and printed form, a record of each child's daily performance.

The design of the study produced the following schedule of events for LOP:

BLOCK	DAY	TASK
A	1-3	Test: Initial
B	4-6	Train I: First training session
C	7	Test: First random 1/3rd test
D,E	8-13	Train II, III
F	14	Test: Second random 1/3rd test
G,H	15-20	Train IV, V
I	21	Test: Third random 1/3rd test
J,K	22-27	Train VI, VII
L	28-30	Test: Final
M	31-33	Test: Retention

If the student was present during a day, then LOP would update his history record and would plan the next day's lesson. Planning the lesson for the next day began with determining the block and the relative day within that block for the student. Then, as appropiate within the schedule listed above, LOP would implement one of the following four procedures:

1. Initial Test. In this procedure the 48 words assigned to the student by the pre-testing were placed in random order and administered to the child in three groups of sixteen. As the performance on each of the sublists was corrected the words were assigned to the experimental or control condition for that child a systematically counter-balenced fashion. For example, the first correctly spelled word in a list would go to the control condition; the next two correctly spelled words would be assigned to the experimental condition; the next two to the control condition and so on. A similar rule was used for assigning words spelled incorrectly on this initial test. At the end of the first three days of the study, each child had his individually determined list structured for him uniquely.

2. Train. For the three day block which involved "training" LOP, on the first day, put all the SOL routine words in random order. Then, on each of the three days of the block, eight words from this list would be chosen. For the words taught under the OEM routine the following rules were used to determine which words to present:

A. Present that item which shows the least number of reinforcements since the last incorrect response. (I.e., subjects always get reinforced after a response so the minimum number is 1, which occurs if the last response was incorrect. The number increases beyond 1 as the string of consecutive responses grows.)

B. In the event of ties under rule A, select from the tied set the items having the least number of total presentations.

C. In the further event of ties under rule B, select with equal probability from this set.

After the items to be presented from both conditions had been selected they were placed in random order and stored as the next day's lesson for the student.

3. Test. Testing days during the run of the experiment involved selecting 8 words with equal probability from the 24 words assigned to each condition. These 16 words were placed in random order and administered to the children.

4. Final Test. Except for the fact no assignment to groups was involved, the final test was administered exactly like the Initial Test.

5. Retention Test. Because of some limitations of time the retention test, given exactly like the final test, took place fairly close to the final test. In practice the time between these last two tests varied between five and ten days.

PROCEDURES

Lesson Material

At the start of the study a pool of 1536 words from the California State Spelling Series (Madden and Carlson,1959) for grades 3-6 were ordered according to the percentage of fifth graders spelling each correctly as reported by Greene (1954) in the New Iowa Spelling Scale. Each child participating in the study was started at a point in this pool and moved up until he started making errors. The errors he made were collected into a list of 48 words which formed his individually developed list. It is from this list that the Lesson Optimizing Routine, described above, developed the child's spelling drill lessons. The actual words used and the number of children using each word appears as Appendix A.

DATA COLLECTED.

The data collected from each word the student was given included whether he was correct or in error and how long it took. If the student took longer than 30 seconds on any word before starting his response it was classed as a special kind of error and recorded separately. Since the difference between errors due to taking too much time and errors due to actual misspelling was of unclear importance, the analysis concentrated on the frequency of correct responses as a function of the tested conditions.

FINDINGS AND ANALYSIS

To evaluate the effectiveness of the two strategies for presenting spelling drill items analyses were performed on the total number of items spelled correctly by each subject over the trial blocks in which all 48 items were presented. Correct responses were chosen for analysis because they are better defined than "non-correct" responses. A response can be incorrect for a number or reasons such as failure to hear the audio message, momentary inattention, typing error, et the total number of items spelled corain ambiguity in how the over-time items should be handled in evaluating the effectiveness of the instructional methods. With responses which are correct none of these problems exist therefore the evaluation was based on the correct responses in each of the 48-word blocks.

The blocks were divided into a "testing" group, containing the initial, final, and retention test blocks (Blocks A,L, and M), and a "training" group composed of those blocks (Blocks B, D, E, G, H, J, and K) administered under the training routine described earlier. An Analysis of Variance model appropiate to the Treatments ⊗ Levels ⊗ Subjects design was used. The summary tables from the analyses appear below as Figures 1 and 2. Of interest is the significant difference obtained between conditions. The differences, also significant, among subjects and blocks are expected from the design of the study.

The differences obtained between the mean scores by conditions implies that one or the other strategy was more successful in producing improved spelling performance. A glance at Figure 3 indicates that the relationship between optimization strategy and increased probability of being correct varies markedly with the type of block. Success, in terms of number of items spelled correctly, is less probable for subjects under the response sensitive, One Element Model based strategy than under the Single Operator Linear model strategy. But this is reversed when one looks at the Final and Retention test blocks.

ANALYSIS OF VARIANCE SUMMARY TABLES

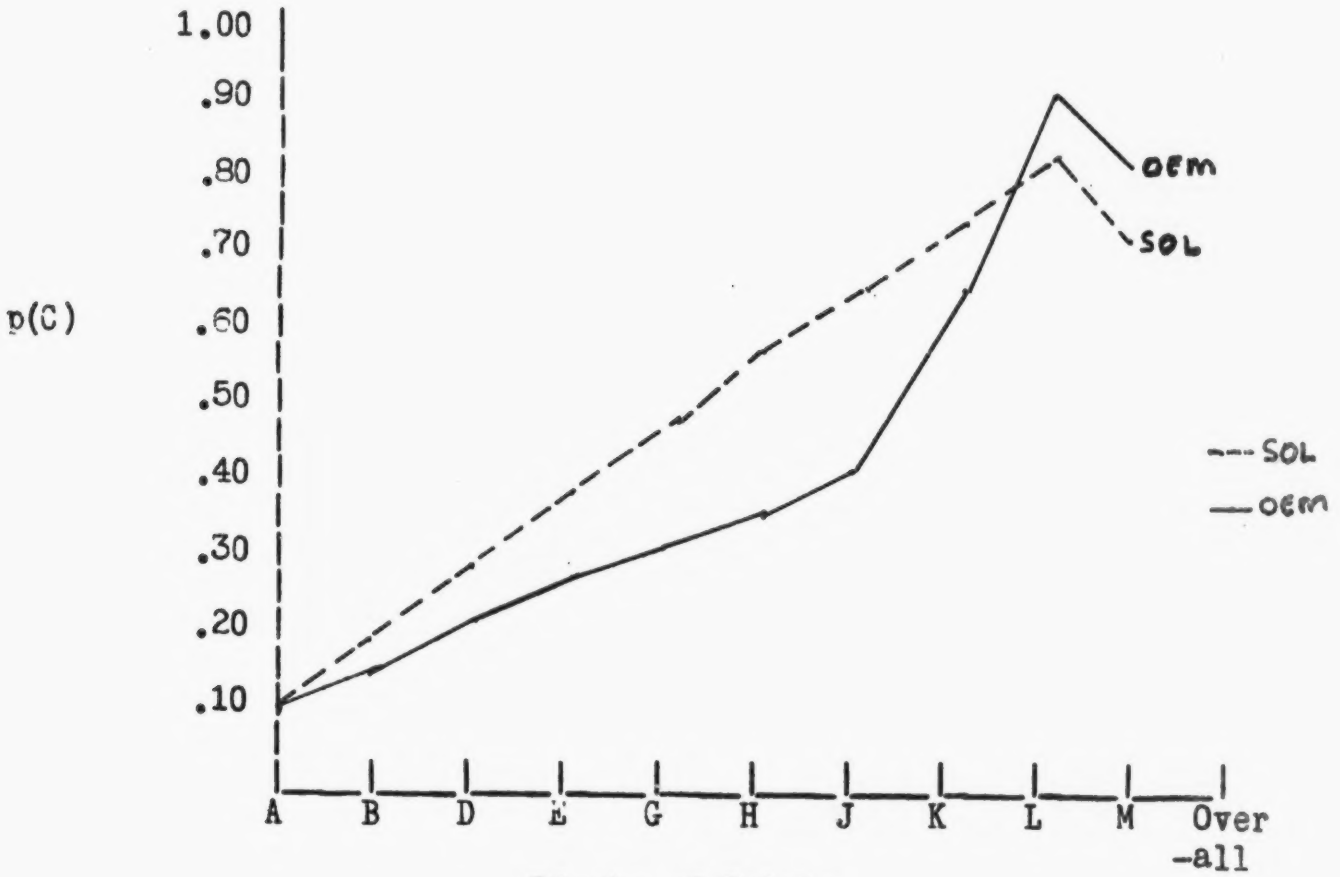
FIGURE 1: Total Correct in Training Blocks

Source	df	Sum of Sqrs	Mean Square	F(df)	Probability
Conditions	1	1455.15	1455.15	866.16 (1/246)	p < .01
Blocks	6	9.13.63	1618.94	963.65 (6/246)	p < .01
Subjects	41	874.20	21.32	12.69 (41/246)	p < .01
C ⊗ B	6	390.64	65.11	38.76 (6/246)	p < .01
C ⊗ S	41	115.92	2.83	1.68 (41/246)	p < .05
B ⊗ S	246	264.80	1.08	.643 (246/246)	not signif.
C ⊗ B ⊗ S	246	412.79	1.68		
Total	587	13227.13			

FIGURE 2: Total Correct in Testing Blocks

Source	df	Sum of Sqrs	Mean Square	F(df)	Probability
Conditions	1	85.75	85.75	47.38 (1/82)	p < .01
Blocks	2	16771.74	8385.87	4633.08 (2/82)	p < .01
Subjects	41	566.18	13.81	7.63 (41/82)	p < .01
C ⊗ B	2	45.02	22.51	12.44 (2/82	p < .01
C ⊗ S	41	79.42	1.94	1.07 (41/82)	not signif.
B ⊗ S	82	125.26	1.53	.845 (82/82)	not signif.
C ⊗ B ⊗ S	82	148.31	1.81		
Total	251	17821.68			

FIGURE 3: Probability of Correct Response



A block by block test of the difference between the means confirms this assessment. The following list of values for Student's "t" was obtained in a block by block assessment of the difference between the means. With 41 degrees of freedom and for a "two-tailed test", t = 2.021 is required for significance at the .05 level; t = 2.704 is required for significance at the .01 level. The difference evaluated is SOL mean - OEM mean.

Block:	A	B	D	E	G	H	J	K	L	M
Diff :	0.0	.96	1.81	2.71	3.19	4.79	5.86	2.03	-1.52	-1.97
"t" :	0.0	1.57	3.23	5.84	7.11	10.04	7.62	3.81	2.80	2.90

The shift in the direction of the difference between the means from the training to the test sessions shows quite clearly the fact that, although the subjects make more errors during training under the One Element Model strategy, they score better on the final tests.

CONCLUSIONS AND RECOMMENDATIONS

The main conclusion from the data analyzed is that, of the two presentation strategies tested in this study, the one developed from the One Element Model of paired-associate learning is most efficient in terms of producing better terminal performance. One important question this result raises is on the nature of the affective outcomes of such an instructional procedure. Especially where disadvantaged youngsters are involved it has been recommended that their opportunity for "success" in school be maximized. If the most efficient learning occurs under a routine that maximizes failure then, perhaps, the student's efforts need to be supported extrinsicly. The variable evaluative comment capacity of the Lesson Implementation Program in this study attempted to provide such support. Because all words were presented to all subjects under this procedure an evaluation of its effectiveness it not possible from this data. Work is in progress to find the effect of such comments.

With the development, in this project, of a more flexible routine for presenting and planning drill lessons in spelling, there is the possibility of moving from a drill-on-words-missed format to an instructional effort that includes some rationale on the structure of the drilled material. While this has been done in arithmatic and, to a degree, in initial reading, it has not been attempted in spelling where the underlying structure of the subject matter is, if it exists, much more difficult to build into a drill based course. Yet, with modifications, the programs developed for this study have the capability of including such an effort.

Finally, although the teachers and students were quite pleased with the project, in general, they did object to one aspect that will always be a problem in a new effort. For example, one of the teachers wrote:

> My suggestions for improvement are few, but definite . I would like to have fewer breakdowns in equipment. This not only frustrates the children but also takes away class time unnecessarily...

While equipment breakdowns are unavoidable, especially in the early stages of innovative efforts such as this, perhaps it would be possible to prepare students and teachers for them by including workshops and visits to the computer facility early in any similar program. It adds an additional expense to such projects but the return in understanding and goodwill from the participants might well prove worth it.

SUPPLEMENTARY AND APPENDIX MATERIALS

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APPENDICES

Appendix A:

WORD LIST

The following list gives the approximate value from the New Iowa Spelling Scale (Greene, 1954). The values, listed in the column labeled "Iowa", represent the percentage of fifth grade children spelling the word correctly in the Greene study. Each of these values had been rounded to the nearest even percent because of space limitations at the time of the study. The figures in the column labeled "N" represent the total number of student word lists on which each word appeared at the start of the study. A total of 69 such lists are represented.

Word	Iowa	N	WORD	Iowa	N
brothers	64	9	says	64	9
lion	64	3	horses	62	5
missed	62	9	while	62	6
silver	62	10	packed	62	6
sew	62	5	center	62	8
dirty	62	13	finds	62	4
farther	62	6	calf	62	3
tooth	62	4	eighteen	62	8
robin	62	8	address	62	7
clothing	62	6	fruit	62	10
travel	62	9	stood	62	5
prince	62	14	corner	62	10
dollars	62	11	held	62	11
nurse	62	9	wrong	62	9
speak	62	6	gloves	62	8
flour	62	10	grapes	62	9
stranger	62	9	lowest	62	3
past	62	5	ruler	62	4
jumped	60	3	which	60	3
learned	60	6	wear	60	4
often	60	6	kept	60	7
month	60	6	raise	60	7
oak	60	4	creek	60	5
shut	60	4	ought	60	6
leather	60	3	steep	60	6

Word	Iowa	N	Word	Iowa	N
lose	60	5	throw	60	4
wrote	60	11	color	60	6
begin	60	3	enjoyed	60	3
nature	60	3	changed	60	3
ladier	60	3			
stayed	58	7	careful	58	5
bother	58	7	amount	58	6
rabbits	58	4	friends	58	11
answer	58	9	fourth	58	5
twelve	58	6	picnic	58	3
stocking	58	3	fought	58	3
sugar	58	11	seemed	58	7
cherry	58	3			
ninth	56	6	marry	56	4
paid	56	8	keen	56	5
cheese	54	6	elephant	54	8
happened	54	4	greatest	54	7
shouted	54	4	sleepy	54	3
melted	54	7	extra	54	5
intend	54	9	queer	54	8
whom	54	5	daily	54	7
copy	54	4	bucket	54	6
music	54	14	upstairs	54	8
scout	54	3	kettle	54	6
visitor	54	3			
flood	52	5	expect	52	11
pour	52	6	among	52	5
pencil	52	14	afraid	52	10
bowl	52	4	package	52	9
toward	52	4	English	52	5
court	52	4	square	52	4
button	52	10			
caught	50	16	pictures	50	5
cute	50	3	voice	50	5
crept	50	5	ladies	50	7
smooth	50	10			
clothes	48	11	second	48	8
truly	48	8	nobles	48	8
freeze	48	6	language	48	8
excited	48	5			

Word	Iowa	N	Word	Iowa	N
whose	46	6	quit	46	5
dried	46	6	honest	46	5
limb	46	3	using	46	4
vacation	46	4			
animals	44	11	though	44	5
po der	44	5	quarter	44	12
escape	44	2	carrying	44	8
shelter	44	12	agreed	44	2
indian	42	7	wor.t	42	3
lying	42	7	dining	42	6
pre-ents	42	12	swimming	42	7
wrist	42	4	chimney	42	5
needle	42	3	rough	42	4
perfume	40	11	theater	40	9
although	40	8	crawl	40	7
questions	40	5	arrived	40	3
signed	40	4	loose	40	4
altogether	40	3	village	40	11
course	40	14			
except	38	4	forgotten	38	3
average	38	4	cousin	38	18
studying	38	11	subject	38	3
serve	38	4	fountain	38	2
palace	38	4	scarf	38	4
entertain	38	13			
surprise	36	8	dropped	36	7
sentence	36	6	chalk	36	8.
weigh	36	5	elevator	36	9
borrow	36	5	throat	36	10
measure	36	6	beautiful	36	11
surely	36	24	slippers	36	4
violin	36	4	curtain	36	5
exciting	36	9	journey	36	8
salad	36	9			
several	34	4	recess	34	7
written	34	5	question	34	5
collar	34	7	waist	34	7
screen	34	10	daughter	34	8
beginning	34	10	interested	34	6
cellar	34	7	quietly	34	7
common	34	11	select	34	12

Word	Iowa	N	Word	Iowa	N
different	32	26	hospital	32	18
awful	32	25	attack	32	10
studies	32	4	attend	32	4
offered	32	13	account	32	17
term	32	12	pattern	32	9
president	30	24	pieces	30	16
receive	30	24	promise	30	3
general	30	7	planning	30	20
section	30	20	grocery	30	8
addition	30	4	geography	30	12
believe	30	4	themselves	30	9
tobacco	30	17	climate	30	5
rifle	28	7	neither	28	9
bananas	28	2	equal	28	8
allowed	28	27	onions	28	19
practice	28	14	possible	28	19
umbrella	28	18	slipped	28	7
dictionary	28	8	pardon	28	19
pitcher	28	28	regular	28	17
frightened	26	18	secret	26	8
against	26	15	million	26	10
example	26	14	certain	26	8
naughty	26	23	electric	26	15
favorite	26	14	pleasant	26	24
vacant	26	7	decorate	26	17
sandwiches	26	22	fortune	26	9
autumn	24	26	niece	24	11
library	24	13	magazine	24	20
honor	24	11	wrap	24	9
automobile	24	16	contries	24	8
soldier	24	7	ghost	24	2
furniture	24	12	industry	24	7
neighbor	24	9	avenue	24	3
balloon	24	19	period	24	8
mischief	24	12			
straight	22	10	buried	22	15
shipped	22	14	envelope	22	19
bicycle	22	23	planned	22	2
whether	22	18	pledge	22	7
direction	22	3	memory	22	9
metal	22	8	science	22	3

Word	Iowa	N	Word	Iowa	N
capital	20	11	education	20	6
accident	20	13	current	20	7
happiness	20	6	amusement	20	7
length	20	17	factories	20	14
machinery	20	6	appointment	20	7
sincerely	20	28	stationery	20	25
special	20	12			
separate	18	4	division	18	14
prettiest	18	17	attention	18	10
attention	18	11	author	18	24
importance	18	15	social	18	6
scene	18	12	equipment	18	13
museum	18	17	method	18	15
exercise	18	16			
ache	16	8	noticed	16	9
funeral	16	12	material	16	12
surrounded	16	13	style	16	9
salute	16	13	manual	16	11
business	16	17	vegetables	16	10
college	16	10	typewriter	16	8
celebrate	16	8	arrange	16	16
opera	14	13	organized	14	15
sense	14	15	citizen	14	7
probably	14	10	excitement	14	6
stomach	14	14	awfully	14	18
chocolate	14	19			
received	12	20	secretary	12	15
certainly	12	12	development	12	18
furnace	12	20	invitation	12	20
community	12	16	article	12	16
finally	10	12	pigeons	10	16
instrument	10	18	disease	10	22
scissors	10	18	groceries	10	5
exhibit	10	13			
examination	8	3	embroidery	8	10
generally	8	4	orchestra	8	10
necessary	8	9			
principal	6	8	gymnasium	6	10
appreciate	4	12	especially	4	12
acquainted	4	12			